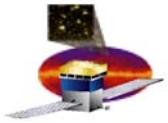


# GLAST LAT Multiwavelength Studies - Overview

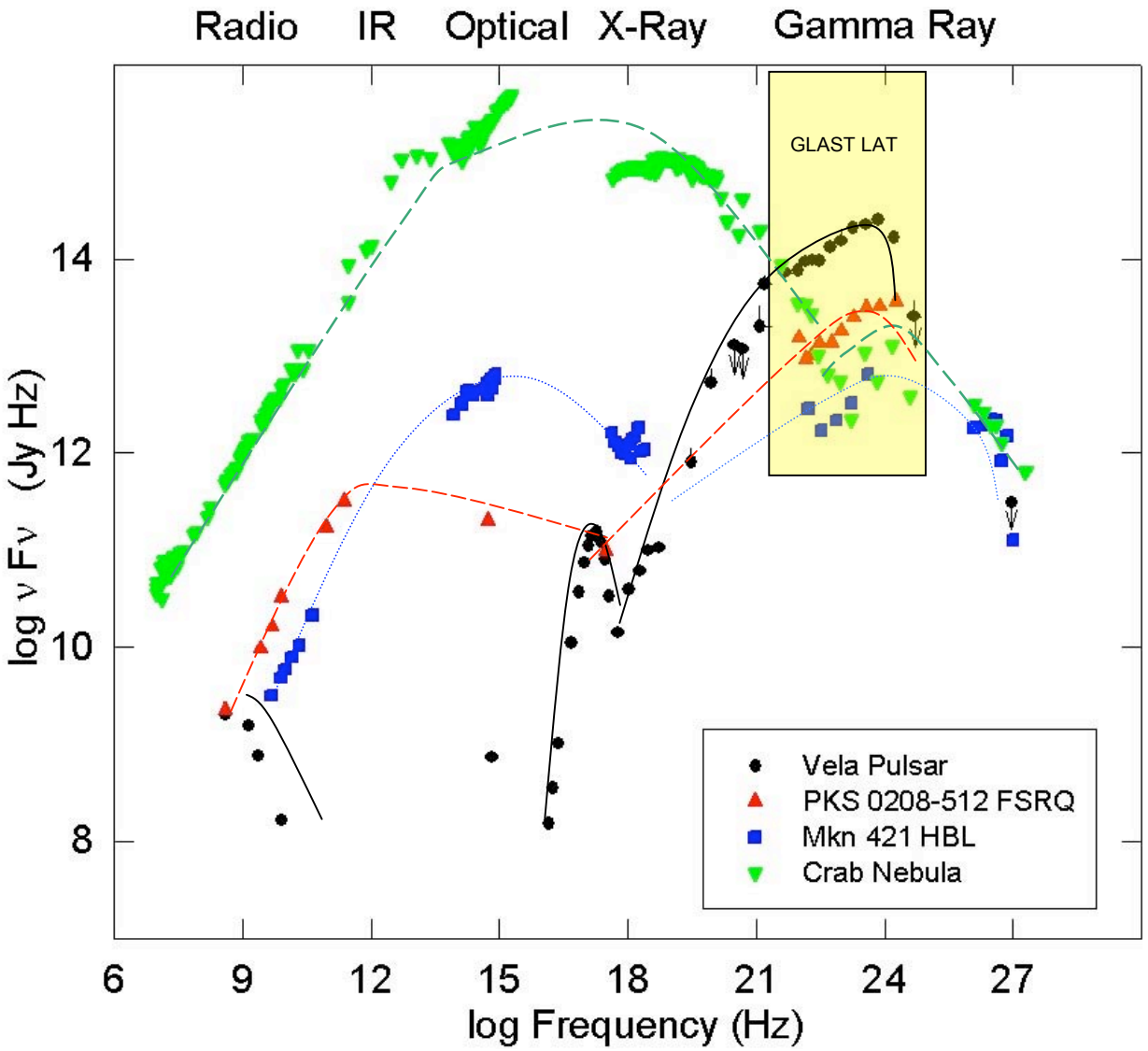
**Dave Thompson**

**GLAST Large Area Telescope**
**Multiwavelength Coordinator**

## 1. Multiwavelength (MW) Opportunities

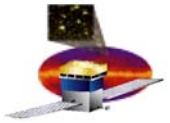
## 2. GLAST Limitations and How We Overcome Them

# Multiwavelength Gamma-ray Sources




Gamma-ray sources are nonthermal, typically produced by interactions of high-energy particles.

Known classes of gamma-ray sources are multiwavelength objects, seen across much of the spectrum.



# GLAST Planning

Both GLAST instruments have huge fields of view.

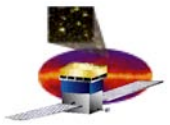
GLAST will be operated in scanning mode.

Both the GBM and the LAT will survey the entire sky about every three hours.

**Whatever your favorite source is, GLAST will observe it.**

**The GBM data (bursts) become public immediately.**

**The LAT data are not generally public during Cycle 1, but there are exceptions, and the LAT team is eager to cooperate with observers with correlative data.**



# GLAST LAT and Other Observatories – Common Scientific Interests

Gamma rays are nonthermal, so sources of interest are those that have hard, nonthermal spectra.

Blazars – LAT will quickly announce flares that can be correlated with data at other wavelengths or used as TOO triggers.

Radio galaxies, galaxy clusters, starburst galaxies, and luminous IR galaxies are potential LAT sources.

Pulsars – a known Galactic gamma-ray source class.

Microquasars, pulsar wind nebulae, and supernova remnants are likely LAT Galactic source classes. Stellar Winds in WR-Binaries and OB associations are potential LAT sources.

As soon as a new source class is suggested in LAT data, the LAT scientists will come looking for cooperative efforts – maybe yours.

# The Challenge of Gamma-ray Source Identification

**With the exception of bright pulsars, no source is likely to be identified using gamma-ray data alone.**

**"Truth in advertising" We do not want to encourage unrealistic expectations.**

**Inherent limitations are due to physics and astrophysics of gamma rays.**

- **Imaging**
- **Spectroscopy**
- **Statistics**

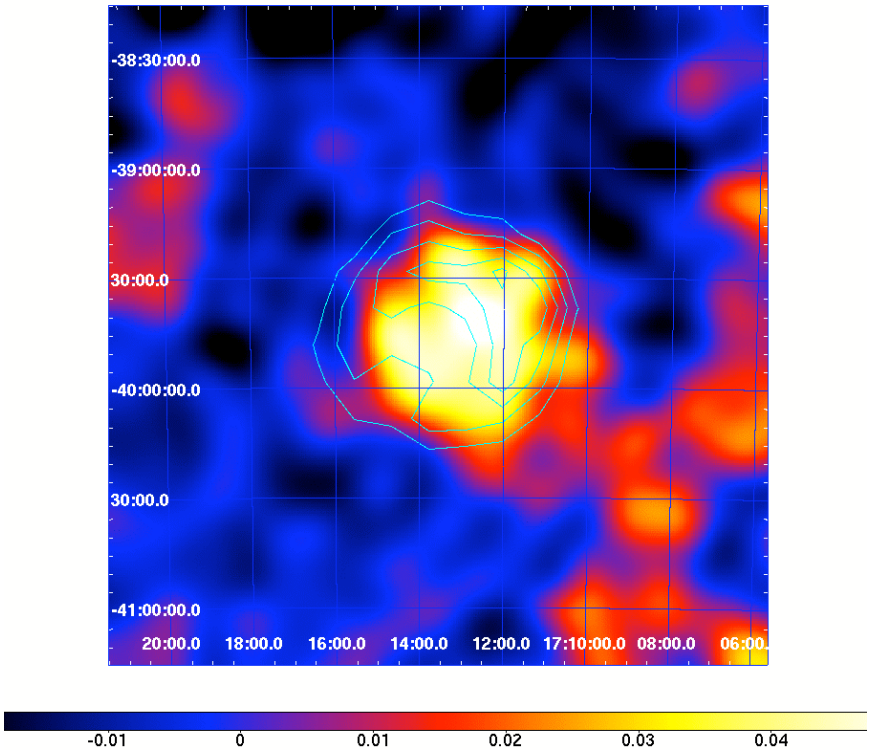
**Reminder: GLAST LAT response functions are still in development. This is all preliminary.**

# High-Energy Gamma-Ray Imaging

**Although bright sources can be localized to better than 1 arcmin, weak source error boxes will be up to 10 arcmin.**

**The PSF is more like 10 arcmin, so the imaging is limited.**

**LAT is unlikely to resolve anything smaller than about half a degree.**

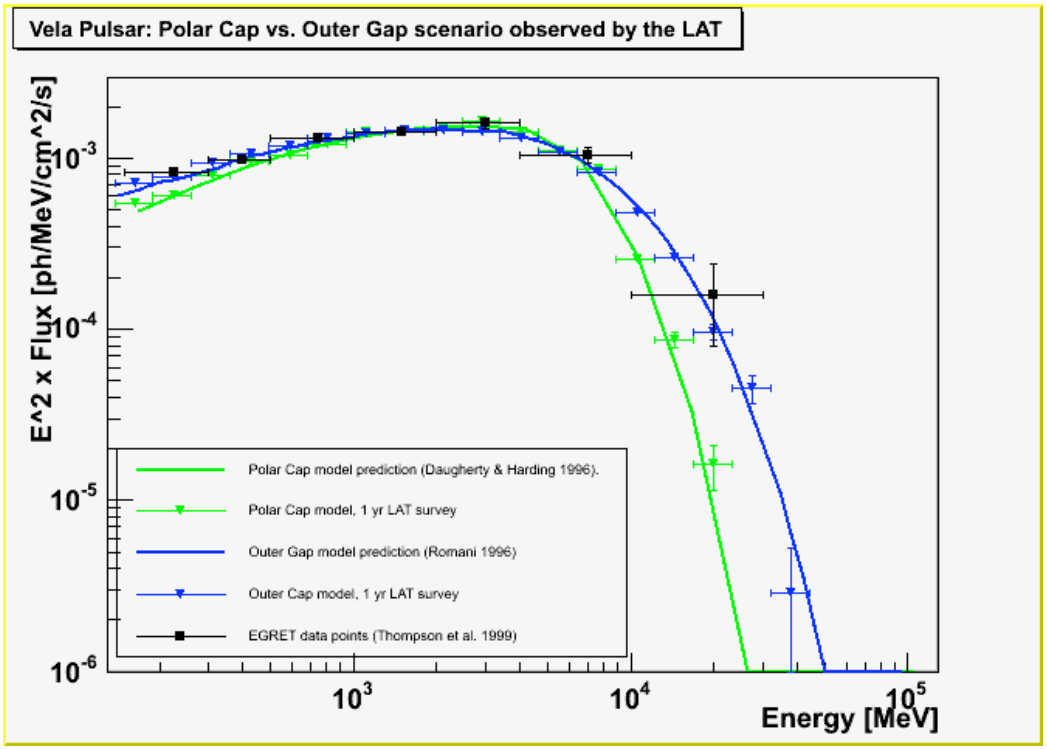



Simulated 5-year LAT image of SNR RXJ 1713.7-3946 (Funk, 2006). The SNR diameter is about 1 degree.

# High-Energy Gamma-Ray Spectroscopy

**There are no high-energy gamma-ray lines that can be used for redshift or abundance measurements.**

**LAT will concentrate on measuring the shapes of continuum spectra.**




Simulated 1-year LAT spectrum from the Vela pulsar, for two models (Razzano, 2006).

# High-Energy Gamma-Ray Statistics

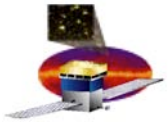
**Except for gamma-ray bursts, none of the sources are bright enough to produce statistically-significant detections of short time variations.**

Time estimates

| Source | l (deg) | b (deg) | z | Flux*/index | Time** |
|---|---|---|---|---|---|
| BL Lac | 92.6 | -10.44 | 0.069 | 11.1 /2.60<br>39.9/2.60 | 20 d<br>2 d |
| 3C273 | 289.9 | 64.4 | 0.158 | 15.4/2.58 | 5.5 d |
| 3C279 | 305.10 | 57.06 | 0.536 | 74.2/1.96<br>1000/2 | 4 h<br>9 min |
| PKS0528+134 | 191.4 | -11.01 | 2.06 | 93.5/2.46<br>300/2.21<br>30/2.5 | 11 h<br>1.4 h<br>3 d |
| PKS2155-304 | 17.73 | -52.25 | 0.116 | 13.2/ 2.35 | 5 d |
| 1ES1959+650 | 98.0 | 17.7 | 0.047 | 13.3/2.45 | 9.5 d |

* [E>100 MeV] $10^{-8}$ ph $cm^{-2}s^{-1}$
** to achieve 5 σ

Estimates of times for source detections with LAT (Lott, 2007).



# Multiwavelength Gamma-Ray Source Identification – Some Possibilities

The GLAST LAT team is developing Figure of Merit approaches for statistical association of sources with possible new classes. We will need some specific examples to confirm such associations.

"Top-Down" approach: look for an X-ray or TeV counterpart with better source localization.

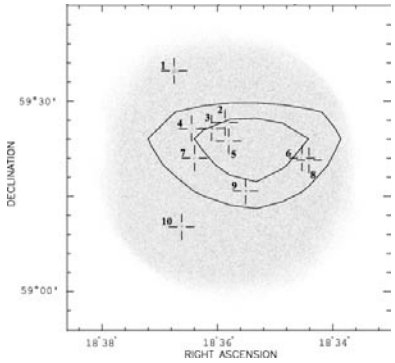
"Bottom-Up" approach: look for a flat-spectrum radio counterpart

"Variability/Spectral Modeling" approach: look for consistency across the spectrum.

Illustrate with the few examples from EGRET where these were possible.

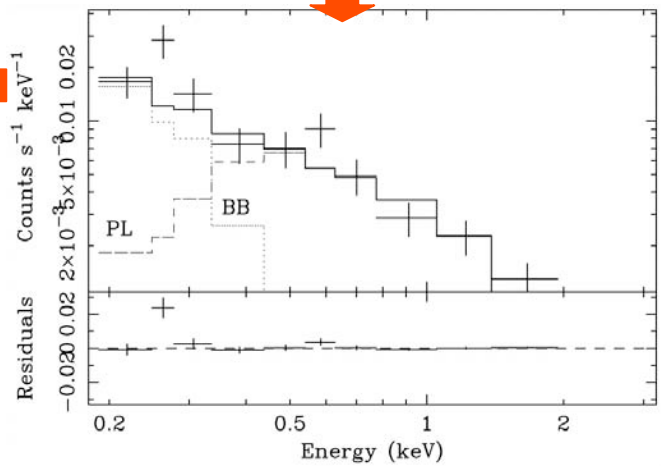
# Top-Down: 3EG J1835+5918

**Parallel effort by two groups, headed by Mirabal/Halpern and Reimer/Carramiñana – used the same approach and reached the same conclusion for 3EG J1835+5918**



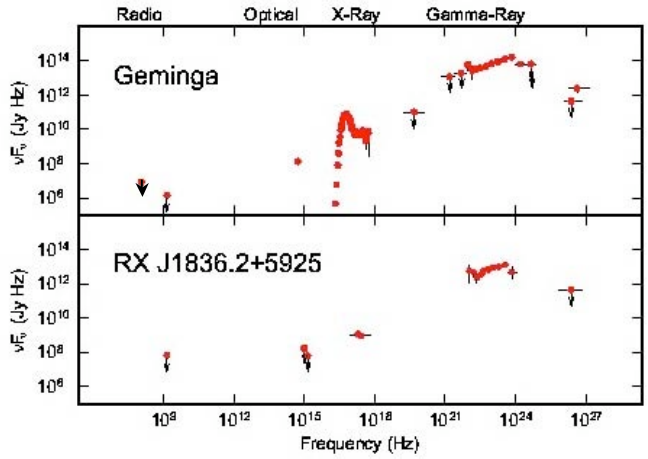

**Start with deep ROSAT image (soft X-rays)**

**Take deep optical images to try to identify all the X-ray sources. Most turn out to be stars or QSOs, unlikely gamma-ray sources. One candidate has no obvious optical counterpart: RX J1836.2+5925.**




**Use Chandra to obtain X-ray spectrum of the candidate: two components, one thermal, one power law.**

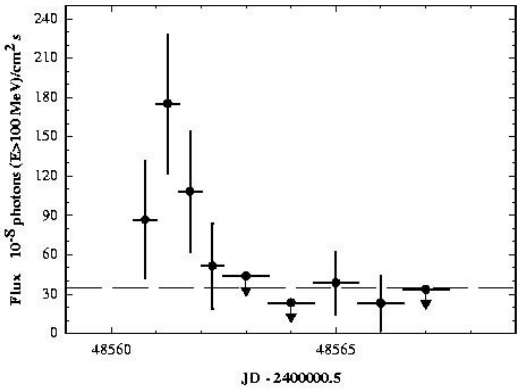
**Use radio search to look for possible radio pulsar. None found.**



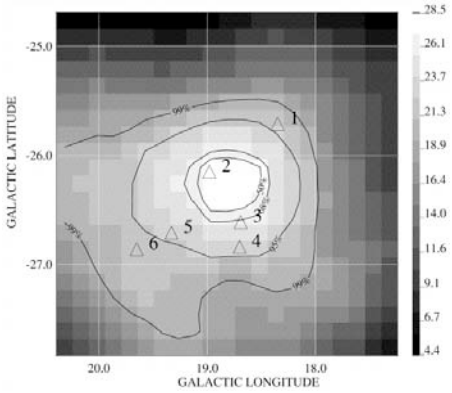

**Construct MW spectrum. It resembles that of Geminga, a spin-powered pulsar. No pulsations have yet been found for 3EG J1835+5918.**

# Bottom-Up: 3EG J2006-2321

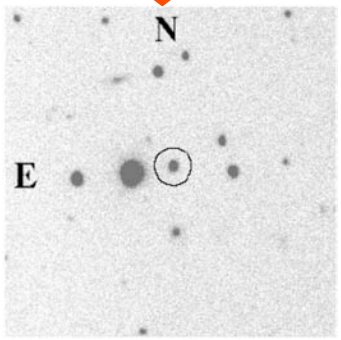
**First Clue: Gamma-ray variability**




**Radio sources in the error box**




One flat-spectrum radio source, 260 mJy at 5 GHz; one marginally-flat source, 49 mJy; other sources are much weaker



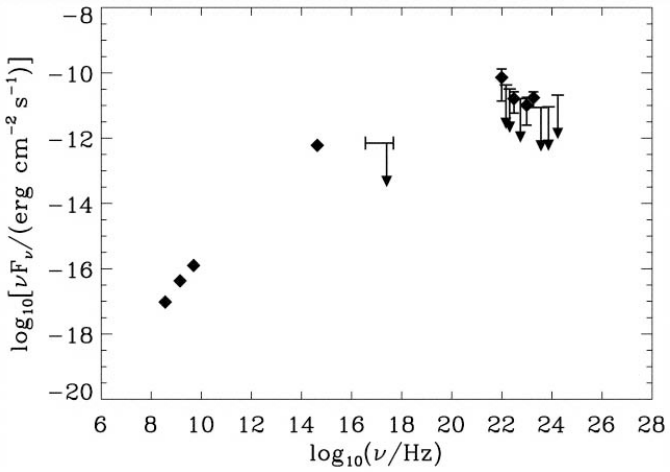

Optical observations:

The 49 mJy source is a normal galaxy;

The 260 mJy source has an optical counterpart with a redshift z=0.83

Variable optical polarization is seen.

Only an X-ray upper limit found.




Spectral energy distribution is bimodal like other blazars

**Conclusion: a flat spectrum radio quasar (FSRQ)**

# Variability/Spectra: 3EG J0433+2908

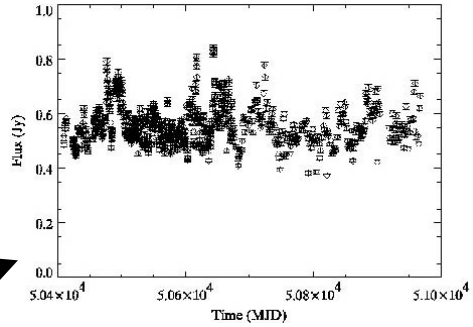
## Assembling the Puzzle (Foreman et al.)

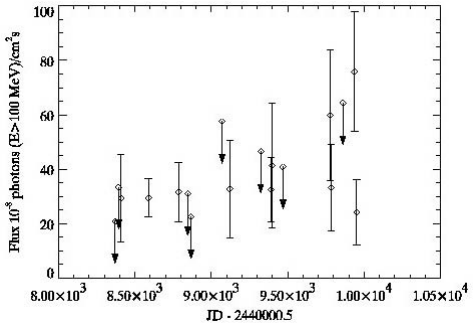
## From catalogs:

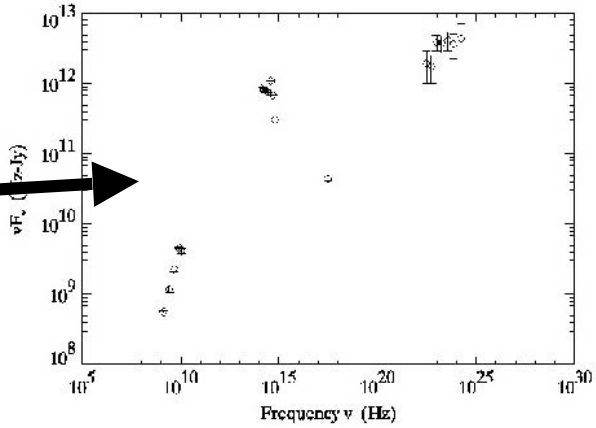
- **Flat-spectrum radio source, 475 mJy at 5 GHz**
- **IR, optical, X-ray source**

## From observations:

- **Radio variability**
- **Gamma-ray variability**
- **Probable optical and X-ray variability**
- Featureless optical spectrum

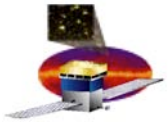



**Spectral energy distribution is bimodal like other blazars**

**Conclusion: probably a BL Lac**



# GLAST Multiwavelength – Summary

**You do not have to be a GLAST scientist to work with the LAT team, even during Phase 1. If your data include a source seen by the LAT, we are interested.**

**There are opportunities for theorists and observers from all wavelengths to help open up the discovery space that GLAST will provide. Join the fun!**